Bellcomm

955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

B71 06017

date: June 17, 1971

to: Distribution

from: W. L. Austin, P. H. Whipple

subject: Controlled Oceanic Impact for Skylab S-IVB Stages - Case 610

ABSTRACT

A well-controlled oceanic impact for the S-IVB stages of the manned Skylab missions can be achieved with an off-perigee spacecraft insertion into an orbit with a 120 nm apogee altitude and a relatively low perigee altitude. The spacecraft would perform an SPS propulsive maneuver at its first apogee to achieve an 81 x 120 nm orbit. The S-IVB continues on its insertion orbit, enters the atmosphere on its first revolution, and impacts in a pre-selected oceanic area. Variations in S-IVB impact point location resulting from various perturbations of the S-IVB trajectory are small. The currently baselined technique is to abandon the S-IVB stages in an 81 x 120 nm orbit. In this case, the S-IVB stages will impact about one day after launch and the impact point may be located anywhere along the ground track at several consecutive orbits.

This S-IVB disposal capability is obtained for no penalty in launch vehicle performance or launch opportunities, and no hardware or software modifications to the launch vehicle or spacecraft are required. The currently baselined rendezvous profile may be used. However, if an Indian Ocean impact location is selected, an additional revolution in the rendezvous phase of the ascent trajectory may be required. An ARIA aircraft located so as to provide communication with the CSM during or shortly after the perigee-lift maneuver is probably required for verification of the maneuver.

(NASA-CR-119312) CONTROLLED OCEANIC IMPACT FOR SKYLAB S-4B STAGES (Bellcomm, Inc.) 23 p

N79-71843

Unclas
00/12 12864

Bellcomm
955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

B71 06017

date: June 17, 1971

to: Distribution

from: W. L. Austin, P. H. Whipple

subject: Controlled Oceanic Impact for Skylab S-IVB Stages - Case 610

MEMORANDUM FOR FILE

I. INTRODUCTION

Previous studies have indicated that large pieces of orbital debris at low altitudes, such as abandoned launch vehicle stages, will experience orbital decay, partially survive the descent through the atmosphere and impact the surface of the earth. In particular, the S-IVB stages of the Skylab SL-2, 3, and 4 launch vehicles are to be abandoned in a 81x120 nm orbit and are expected to impact the earth in a little more than one day after launch. The impact point location is highly uncertain. Variations in the atmospheric density alone can cause the impact point to occur up to two revolutions from the nominal impact point.

This memorandum describes a method of providing a controlled impact point in a pre-selected oceanic area for a Skylab S-IVB stage. The basics of the method will be discussed in Section II and example cases with nominal impact points in the Indian and Pacific Oceans will be given. Variations in impact point location resulting from variations in launch vehicle performance, S-IVB coefficient of drag, and atmospheric density will also be discussed, as will launch window and rendezvous considerations.

II. DISCUSSION

A. Description of S-IVB Disposal Method

The current nominal mission profile for a manned Skylab mission includes a launch into the perigee of an 81x120 nm earth orbit. At the second apogee, the CSM makes the first in a sequence of propulsive maneuvers which accomplish a rendezvous with the Orbital Assembly (OA). The method of S-IVB disposal to be discussed here consists of inserting the CSM at an off-perigee condition such that the rendezvous capability of the spacecraft is preserved, and a well-controlled S-IVB decay trajectory to a pre-selected impact area is achieved. After insertion and separation of the CSM from the S-IVB stage, the CSM and S-IVB are in orbits with an apogee altitude of 120 nm and relatively low perigee altitudes. At the first CSM apogee, which occurs within the first half-orbit, the CSM raises its perigee altitude to 81 nm with a perigee-lift maneuver using the Service Propulsion System (SPS). It is envisioned that the perigee lift maneuver would be a simple, horizontal delta-v maneuver of fixed magnitude with no ground support or on-board targeting required. At most, a crew chart might be carried to determine the delta-v required to account for substantial insertion dispersions. The CSM then proceeds to rendezvous with the OA in essentially the same manner as currently planned. The Reaction Control System (RCS) is available as a backup propulsion system for the perigee-lift maneuver. The S-IVB stage remains in a low perigee orbit, encounters the atmosphere on its first revolution, and impacts in an area determined by its aerodynamic characteristics and its orbital characteristics at entry into the atmosphere.

Shown in Figure 1 is the oceanic portion of the first revolution ground track. Except for the excluded areas that include islands, the desired impact point of the S-IVB can be taken at any point on this ground track. Two impact points, located in the Indian Ocean at a longitude of 105 degrees and in the Pacific Ocean at a longitude of -123 degrees, were selected for further study.

Shown in Figure 2 are the orbital conditions required at spacecraft insertion to achieve (1) a first CSM apogee altitude of 120 nm within the first half-orbit, and (2) a nominal S-IVB impact in the Indian Ocean at a longitude of 105 degrees. The flight path angle at insertion and the perigee and apogee altitudes of the insertion orbit are plotted as a function of the insertion altitude. An example of this family of insertion orbits consists of an insertion altitude of 82.2 nm, an insertion flight path angle of .9 degrees, and an insertion orbit with a perigee altitude of about -1 nm and an apogee altitude of about 120 nm. Details of an investigation of this example trajectory will be given later in this memorandum.

Shown in Figure 3 are the orbital conditions required at spacecraft insertion to achieve a first CSM apogee altitude of 120 nm and a nominal S-IVB impact in the Pacific Ocean at a longitude of -123 degrees. An example of this family of insertion orbits which will be discussed further consists of an insertion altitude of 76.7 nm, an insertion flight path angle of .5 degrees, and an insertion orbit with a perigee altitude of about 53 nm and an apogee altitude of about 120 nm.

The data for Figures 2 and 3 were obtained from computer-simulated trajectories generated with the Bellcomm Apollo Simulation Program. The vehicle characteristics used for the S-IVB and CSM are shown in Table 1. Except for the CSM weight, these data were taken from References 1 and 2. The CSM weight was taken to be the SL-2 control weight of 31000 lbs. This is several hundred pounds greater than the current CSM weight and, as shall be shown later, is sufficient to carry the additional SPS propellant required for the perigee-lift maneuver.

The S-IVB was assumed to be in a nose-on attitude for 15 minutes after insertion and tumbling thereafter to impact.

B. Investigation of Selected Examples

The specific insertion orbits selected in the previous section were examined to determine the effects of variations in the atmospheric density, S-IVB coefficient of drag, and insertion conditions on the S-IVB impact point location. Also, differences in the launch trajectory and rendezvous opportunities, and the requirements of the perigee-lift maneuver were examined.

1. S-IVB Impact Point Dispersions

Computer simulated decay trajectories for the S-IVB were generated for several off-nominal conditions to determine the sensitivity of the impact point location to various perturbations. The S-IVB decay trajectories that were generated are listed below:

a. Nominal

b. Maximum drag (+10% error in S-IVB coefficient of drag and +2 sigma atmospheric density)

c. Minimum drag (-10% error in S-IVB coefficient of drag and -2 sigma atmospheric density)

d. ± 3 sigma radial position dispersions at insertion.

e. ± 3 sigma velocity magnitude dispersions at insertion.

The atmospheric density model used was the MSFC special 1962 dynamic model with solar activity predicted for May 1, 1973. The three sigma radial and velocity insertion dispersions were taken from Reference 3 and were 2106 feet and 5.61 fps respectively.

Shown in Figure 4 are the loci of impact points resulting from the above perturbations. Clearly, the S-IVB impact point is well controlled. The footprints containing the S-IVB impact points resulting from the above perturbations are only 408 nm long for the Indian Ocean impact, and 1160 nm long for the Pacific Ocean impact.

2. <u>Launch Trajectory Considerations</u>

Since a launch trajectory different from the currently baselined trajectory is being considered here, a number of critical parameters concerning the trajectory must be evaluated. These include the payload capability, the maximum dynamic pressure (q max), aerodynamic heating indicator (AHI) at insertion, the dynamic pressure (q) at the time of launch escape system (LES) jettison and at insertion, and the minimum time of free fall (T_{ff}) to an altitude of 300000 feet after LES jettison. (The time of free fall to 300000 feet should be greater than 100 seconds from the time of LES jettison until insertion. This provides adequate time for Command Module/Service Module separation and Command Module orientation to an entry attitude in the event of an abort.) This data is presented for the two example launch trajectories in the following table.

	Indian Ocean Impact	Pacific Ocean Impact
Insertion Altitude, nm	82.2	76.7
Insertion FPA, Deg	0.9	0.5
Payload Gain at Insertion, Lbs*	443.	246.
q Max Increase*	.5%	.8%
AHI Increase*	2.2%	2.6%
q at LES Jettison, psi	.0024	.0025
q at Insertion, psi	.0000048	.0000077
Min. t_{ff} after LES Jettison, Sec	148.	137.

*Relative to a launch trajectory into a perigee of an 81 x 120 nm insertion orbit.

It is clear that no significant problems arise during launch into these insertion orbits. There are only very small changes in the maximum dynamic pressure and AHI, and other abort and dynamic pressure requirements are met.

3. Perigee-Lift Maneuver Requirements

The perigee-lift maneuver is required at the first CSM apogee to raise the perigee altitude to 81 nm. Shown below are the characteristics of this maneuver for the selected insertion orbits and for the SPS and RCS systems respectively. The RCS data are based on a local horizontal fixed attitude burn initiated five minutes after apogee passage.

	Indian Ocean SPS	Indian Ocean RCS	Pacific Ocean SPS	Pacific Ocean RCS
Delta-v, fps	150	197	50	58
Burn Duration, Sec	7.0	469	2.3	139
Propellant, Lbs	460	694	153	205

As would be expected, the propulsive requirements for the Indian Ocean impact location are more severe than for the Pacific Ocean impact due to the much lower initial perigee altitude. While the additional SPS propellant required for the Indian Ocean impact location is slightly greater than the payload gain shown in the previous section, this difference is only 17 lbs and is not considered to represent a payload problem.

The RCS propellant required for a backup perigee-lift maneuver is not a payload consideration. In the event of an SPS failure, the nominal mission could not be completed and the RCS propellant that would have been used in the nominal mission is sufficient for a perigee-lift maneuver and a deorbit burn. However, it may be preferable in this situation not to continue to orbit with the RCS but to return to earth immediately and use the RCS system for adjustment of the entry trajectory if that is required.

4. Launch Window and Rendezvous Considerations

The SL-2 launch opportunities and pre-NC1 MSFN tracking coverage for the two examples were generated in order to compare them with the current baseline. The rendezvous profile assumed is identical to the current baseline except for the addition of the perigee-lift maneuver at first apogee.

Two of the effects of inserting at the altitudes and insertion orbits described for the Indian and Pacific Ocean S-IVB impact cases is to reduce the time between CSM insertion and the NC1 maneuver and increase the time between the NSR and TPI maneuvers. The net effect of these time changes is a reduction in the phase angle caught up by the CSM between insertion and TPF, regardless of M number. Thus, for the same M number, the launch opportunities for the example cases start earlier in the launch window than for the current baseline. This can be seen by comparing Figures 5, 6, and 7 which show the SL-2 launch opportunities for the current baseline and the two example cases. These data were generated using the Bellcomm Apollo Simulation Program, assuming an SL-1 launch on April 30, 1973 at 12:30 p.m. EST.

As can be seen from the figures, the maximum shift in the time of launch pane occurrence is about 1.7 minutes (Indian Ocean S-IVB impact compared to the current baseline). The shift for the Pacific Ocean S-IVB impact case is about 4.0 minute. For days 1 and 6 the earlier launch occurrences are beneficial in that the launch opportunities are longer. The day 2 and day 7 opportunities are shortened by the earlier occurrence of the launch opportunities, but not significantly. In any case, the SL-1 insertion descending node could be shifted to null out these differences if required. (Shifting the node would result in a decrease in the amount of yaw steering required of the SL-1 launch vehicle.)

Since NC1 is baselined as a ground-computed maneuver, the pre-NC1 tracking coverage available is of critical importance. The minimum tracking coverage requirements for a ground-computed maneuver are one range and range rate pass (at least three minutes long) followed by an uplink pass no earlier than ten minutes after the last range and range rate data point (to be used in the computation) is taken. Also, the uplink must not occur less than ten minutes prior to the maneuver. The ten minute intervals are to allow for maneuver computation and verification.

Figure 8 shows the pre-NC1 tracking coverage available for the current baseline and the two example cases for a center-of-the-window SL-2 launch opportunity. The pre-NC1 tracking coverage for off-center-of-the-window SL-2 launch opportunities and for SL-3 and SL-4 launch opportunities will not differ significantly from that shown. The names, abbreviations, and locations of the tracking stations used are shown in Table 2.

For the current baseline and the Pacific Ocean S-IVB impact case, the minimum tracking coverage requirements are met for the NC1 maneuver computation. For the Indian Ocean S-IVB impact case however, the NC1 maneuver occurs in view of the Madrid station and the time available for uplinking the maneuver solution is inadequate. The situation can be remedied by inserting an additional orbit between the perigee-lift maneuver and NC1. The resulting launch windows are shown in Figure 9. Note however, that this eliminates the M=5 rendezvous opportunities (the new minimum would be M=6).

MSFN coverage of the perigee-lift maneuver is not available for either of the example cases. In fact, there is no coverage prior to the next CSM perigee. Since it is obviously desirable that the ground knows the outcome of the maneuver within a short time after it is to be performed, it may be desirable to station an ARIA aircraft at an appropriate location.

III. Conclusions

The off-perigee insertion method of controlling the S-IVB impact point has been shown to be very effective. For selected example impact areas in the Indian and Pacific Oceans, variations in the impact point locations resulting from various perturbations to the S-IVB decay trajectory are small and impact always remains well within desired oceanic areas.

This impact point control is obtained for no penalty in launch vehicle performance, launch opportunities, or in hardware or software modifications to the launch vehicle or spacecraft. The extra CSM propulsive maneuver required to raise the insertion perigee altitude can be performed by either the SPS or RCS propulsion system. If an Indian Ocean impact point is selected, it may be necessary to increase the interval between orbital insertion and rendezvous with the OA by one orbit.

It is probably desirable to station an ARIA aircraft such that ground verification of the perigee-lift maneuver can be obtained well before the next CSM perigee.

IV. Acknowledgment

The work reported in this memorandum is a result of a suggestion originally made by D. R. Hagner to control the S-IVB impact point by changing the insertion orbital

conditions. Appreciation is due also to D. A. Corey of Bellcomm and E. M. Henderson of MSC for pertinent advice and suggestions.

W. L. Austin

W. L. Austin

P. H. Whipple

WLA
1025-PHW-li

P. H. Whipple

Attachments

References

1. Dreher, Percy, Lifetime and Decay Analysis for the Skylab Mission, MSFC-S&E-AERO-MM-59-70, December 2, 1970.

2. Johnson, Josh D., Orbital Aerodynamic Data for the LM/ATM and the CSM, MSFC-S&E-AERO-AD-69-29, May 28, 1969.

3. Bailey, William R., Launch Vehicle Baseline Reference Trajectory Dispersion Analysis (50 Degree Inclination), MSFC-S&E-AERO-MCS-25-70, May 15, 1970.

4. Skylab A Weight and Performance Report, SE-016-001-1, April, 1971.

Table 1

Vehicle Characteristics

S-IVB

REF. AREA 360 SQ. FT.

WEIGHT: 27999 LBS.

CD: NOSE-ON ATTITUDE →2.6305

TUMBLING →5.20

CSM

REF. AREA 360 SQ. FT.

WEIGHT: 31000 LBS.

CD: .857 (α=0)

Table 2

STATION NAMES AND ABBREVIATIONS

STATION NAME	LOCATION		ABBREVIATION
	Latitude	Longitude	
Ascension Island	7.955S	14.328N	ACN
Bermuda	32.351N	64.658W	BDA
Canary Island	27.765N	15.635W	CYI
Canberra	34.415S	148.977E	CNB
Carnarvon	24.908S	113.724E	CRO
Corpus Christi, Texas	27.654N	97.378W	TEX
Goldstone	35.342N	116.873W	GDS
Guam	13.309N	144.734E	GWM
Hawaii	22.125N	159.665W	HAW
Madrid	40.455N	4.167W	MAD
Merritt Island	28.508N	80.710W	MIL
Network Training Facility*	38.970N	76.676W	NTF
Santiago	32.978S	70.669W	SAN

*NTF is located at the Goddard Space Flight Center and there is a strong possibility it will be available (transmitting and receiving) for the rendezvous portions of the Skylab mission.

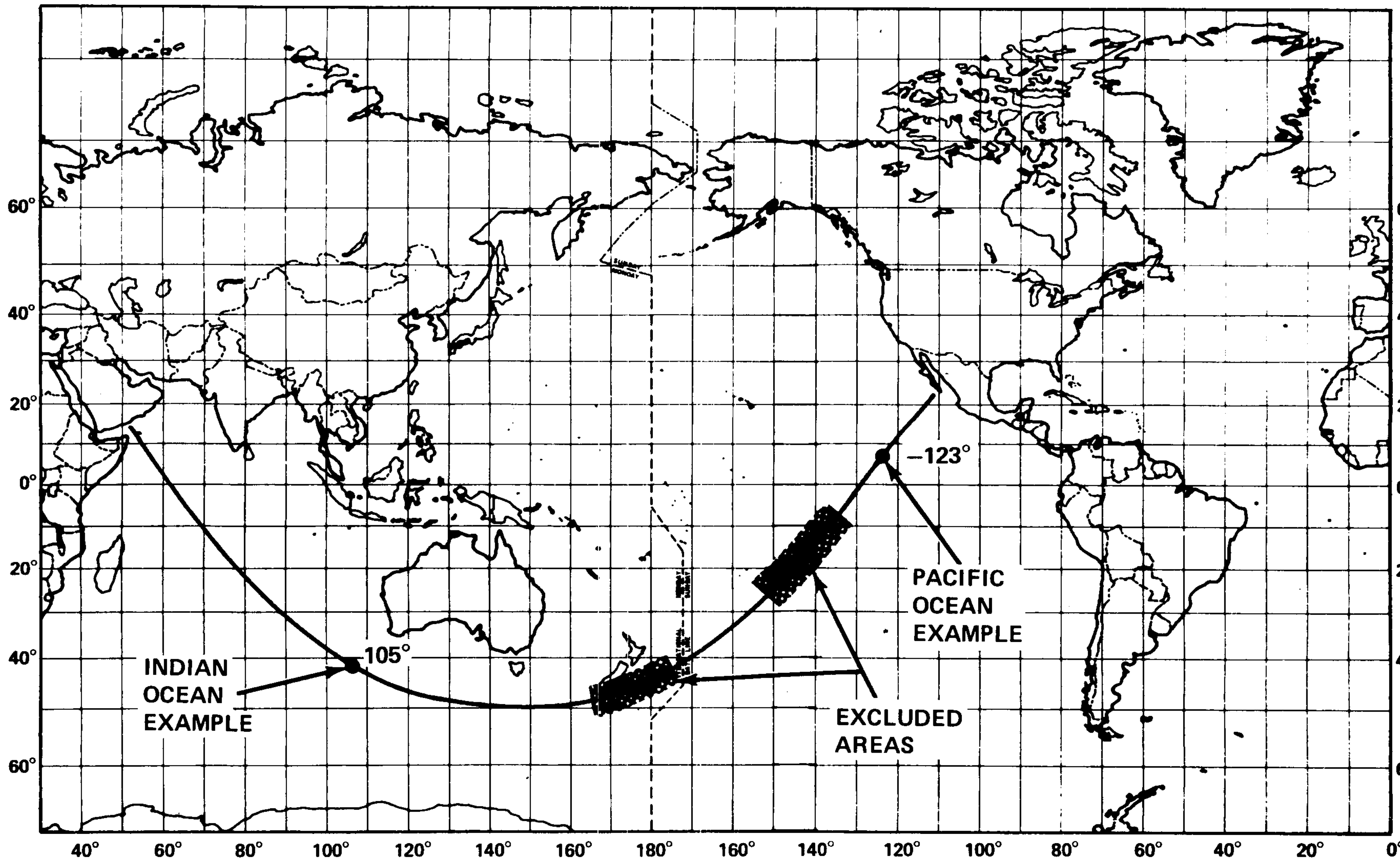

FIGURE 1 - 1ST REVOLUTION GROUND TRACK

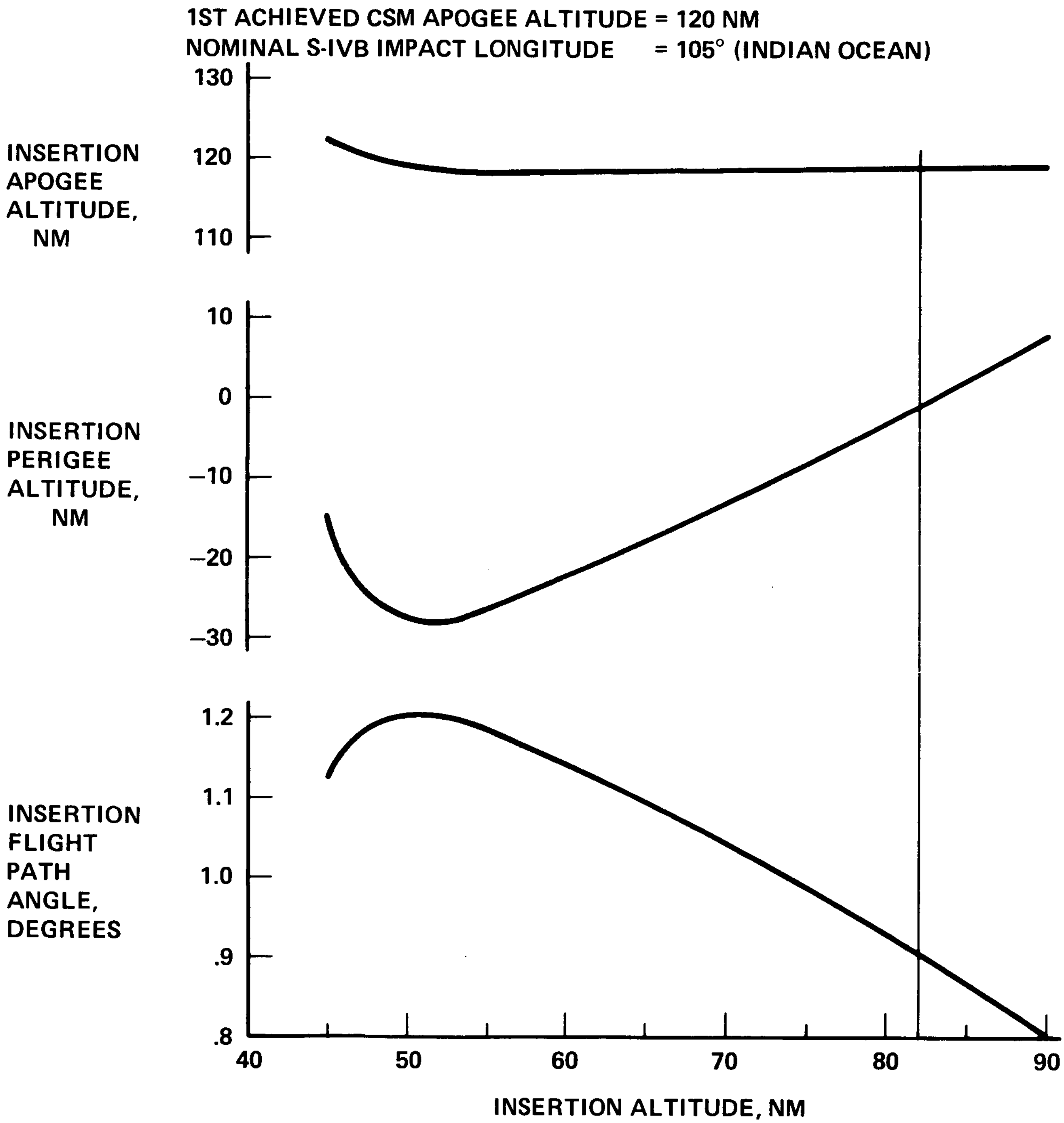

FIGURE 2 - INSERTION ORBIT CHARACTERISTICS FOR S-IVB INDIAN OCEAN IMPACT

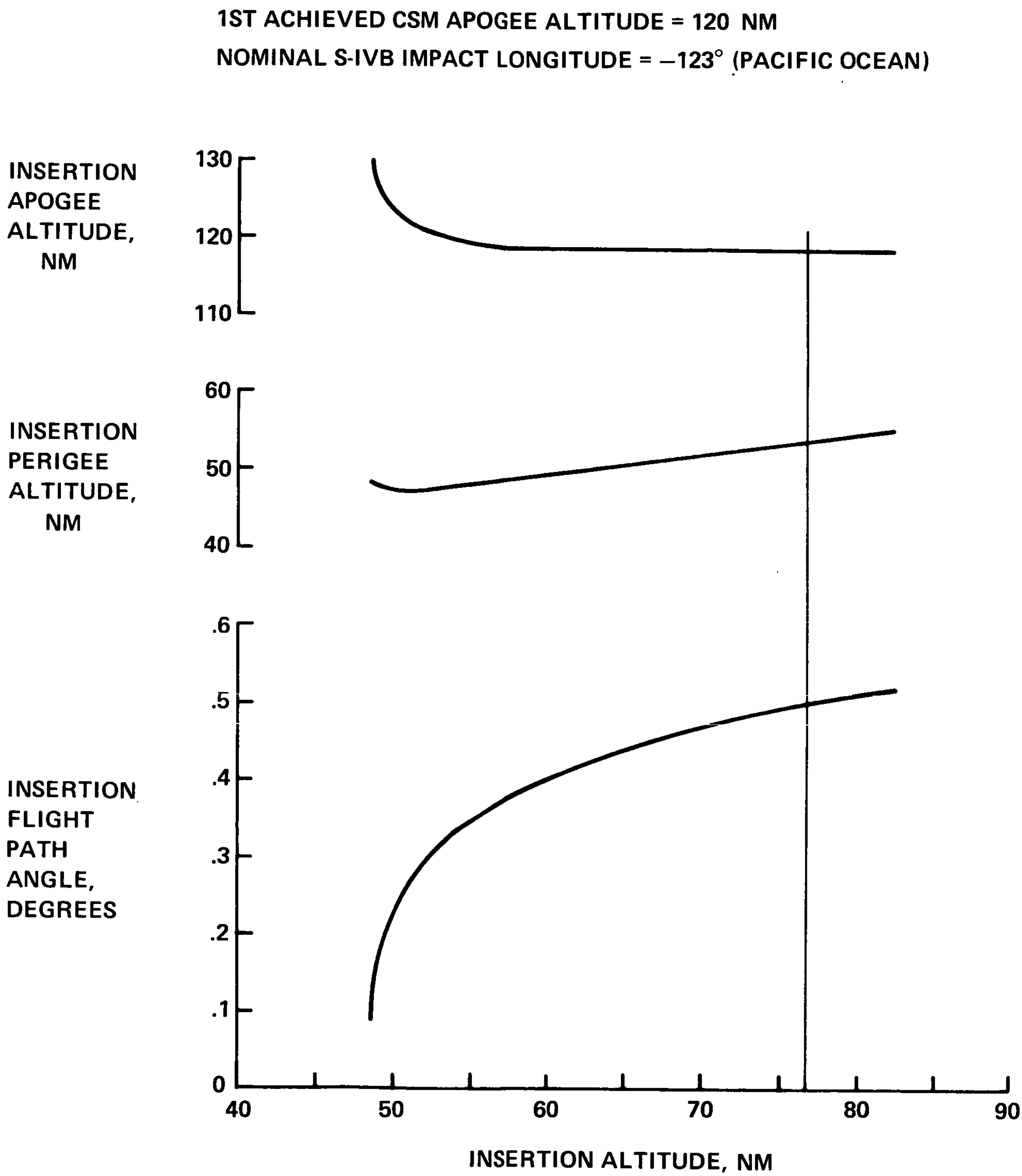

FIGURE 3 - INSERTION ORBIT CHARACTERISTICS FOR S-IVB PACIFIC OCEAN IMPACT

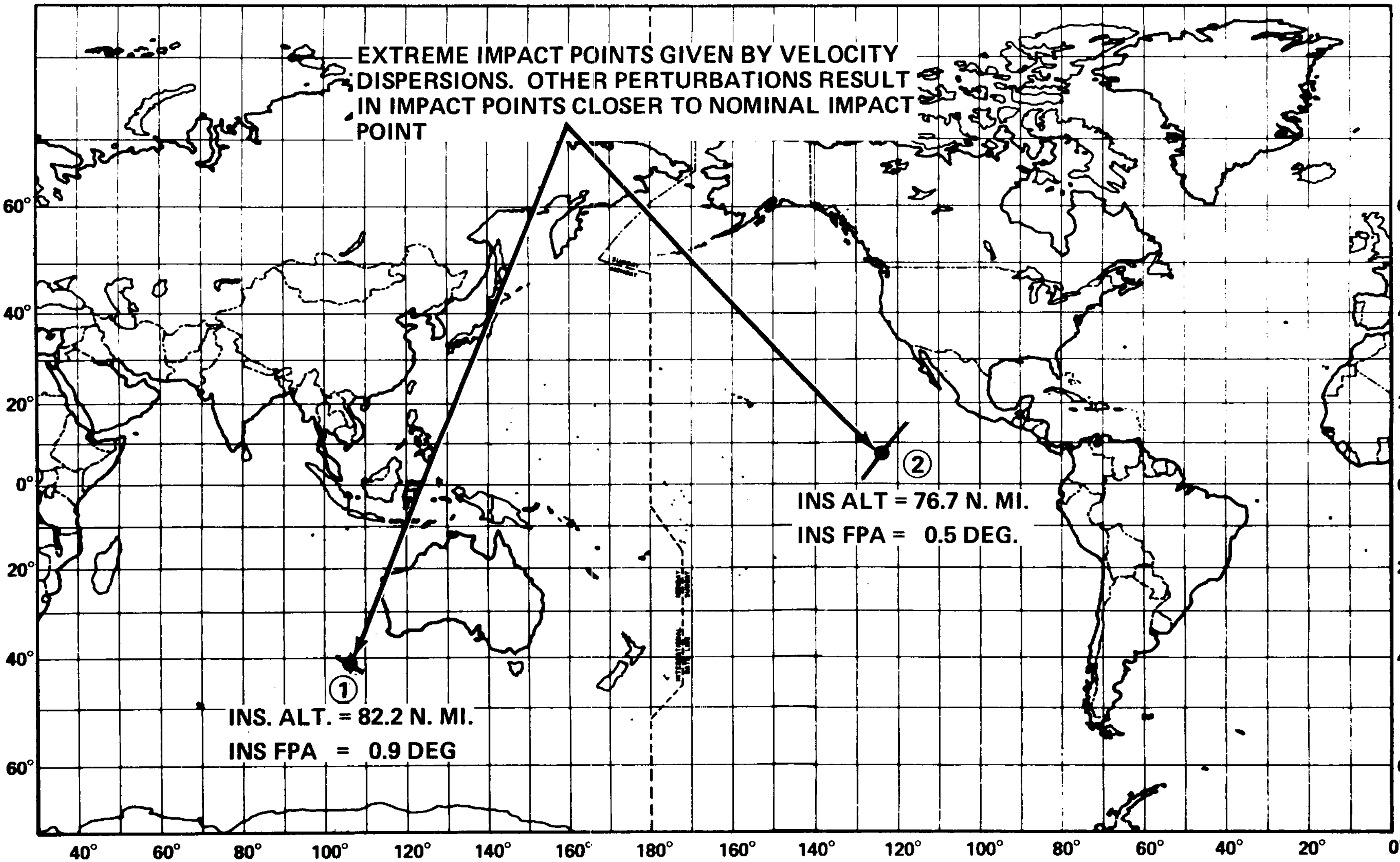

FIGURE 4 - S-IVB IMPACT POINTS RESULTING FROM PERTURBATIONS ABOUT SELECTED NOMINAL INSERTION ORBITS

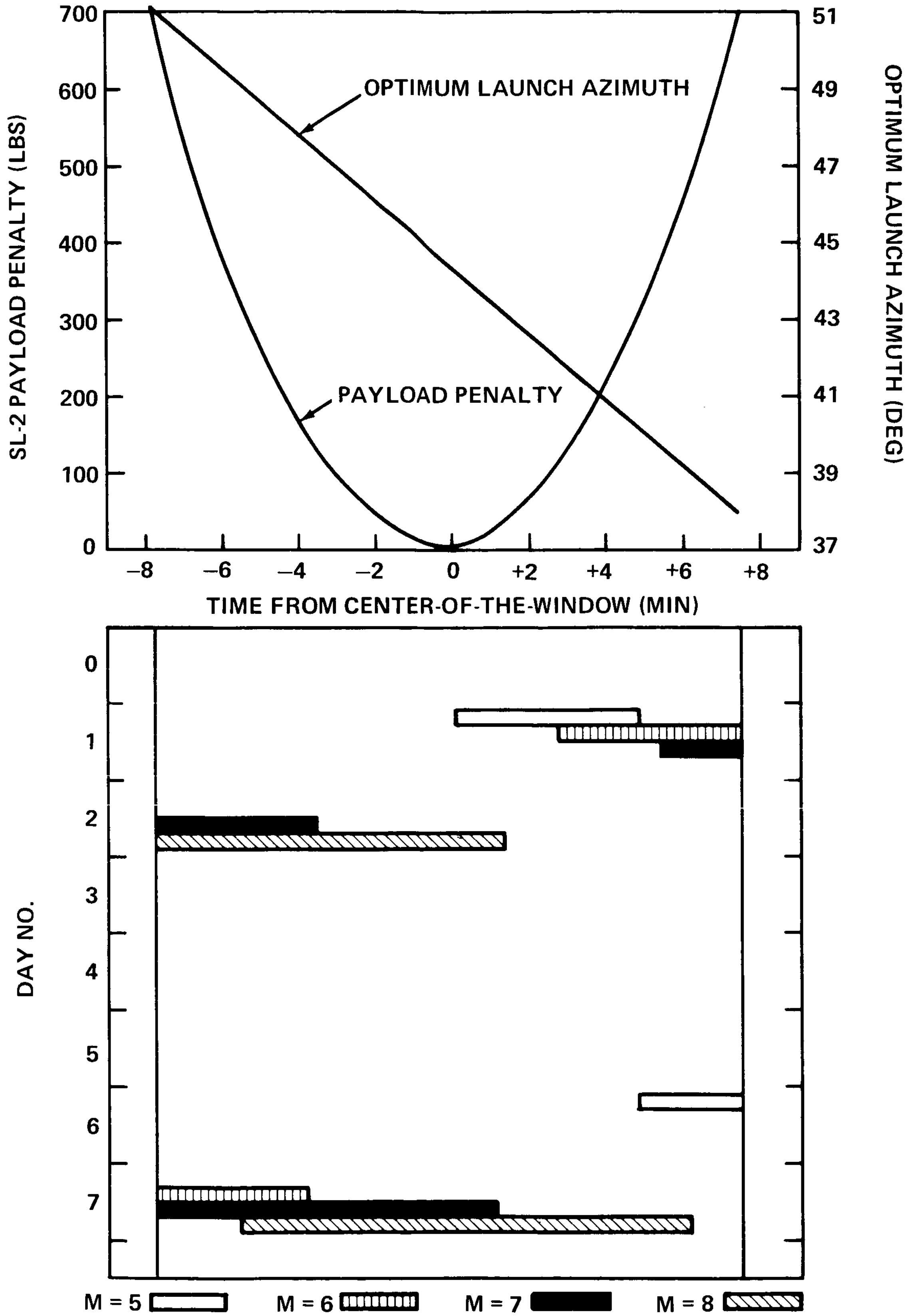

FIGURE 5 - SL-2 LAUNCH OPPORTUNITIES, NOMINAL PROFILE

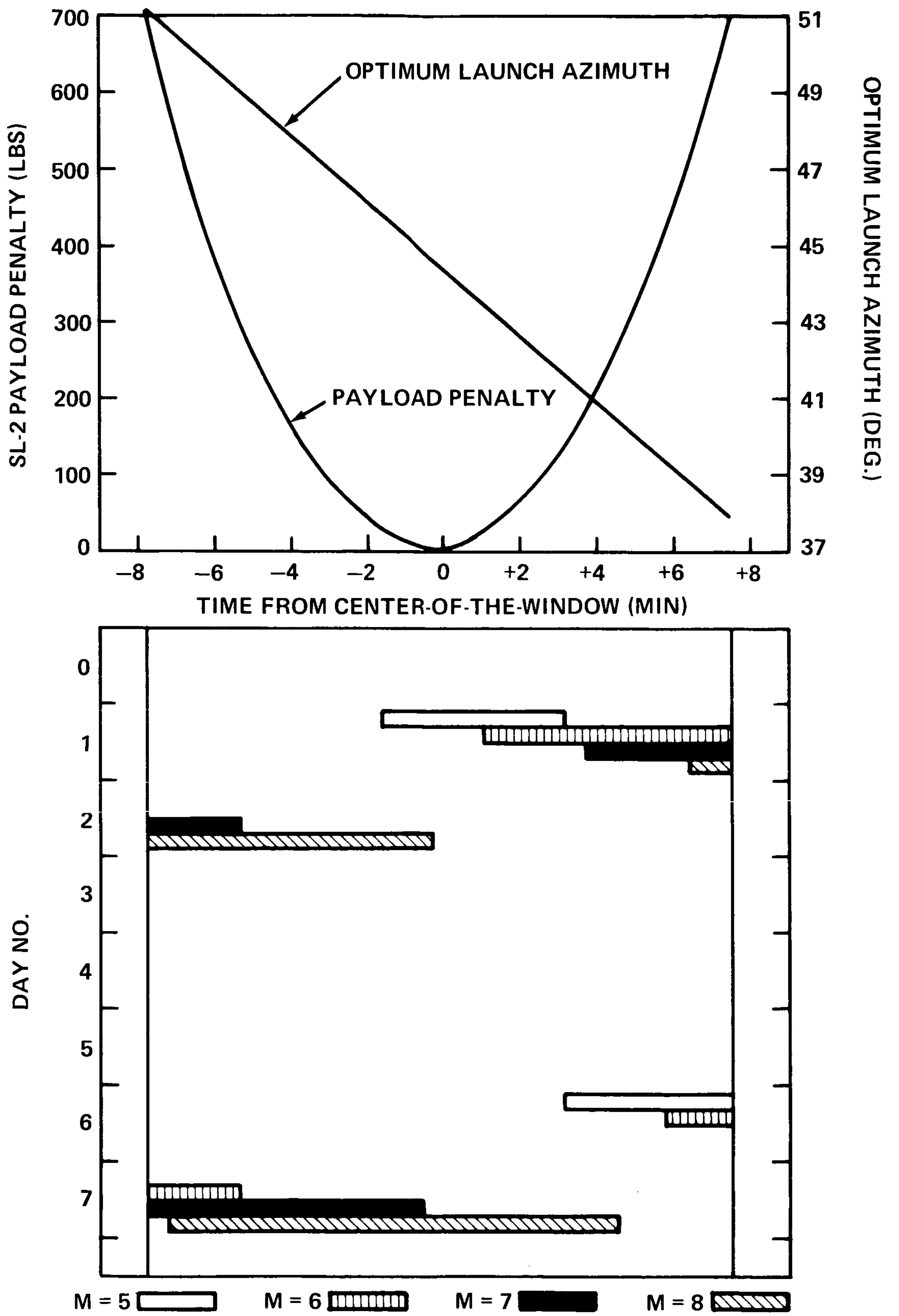

FIGURE 6 - SL-2 LAUNCH OPPORTUNITIES EXAMPLE 1 (INDIAN OCEAN IMPACT)

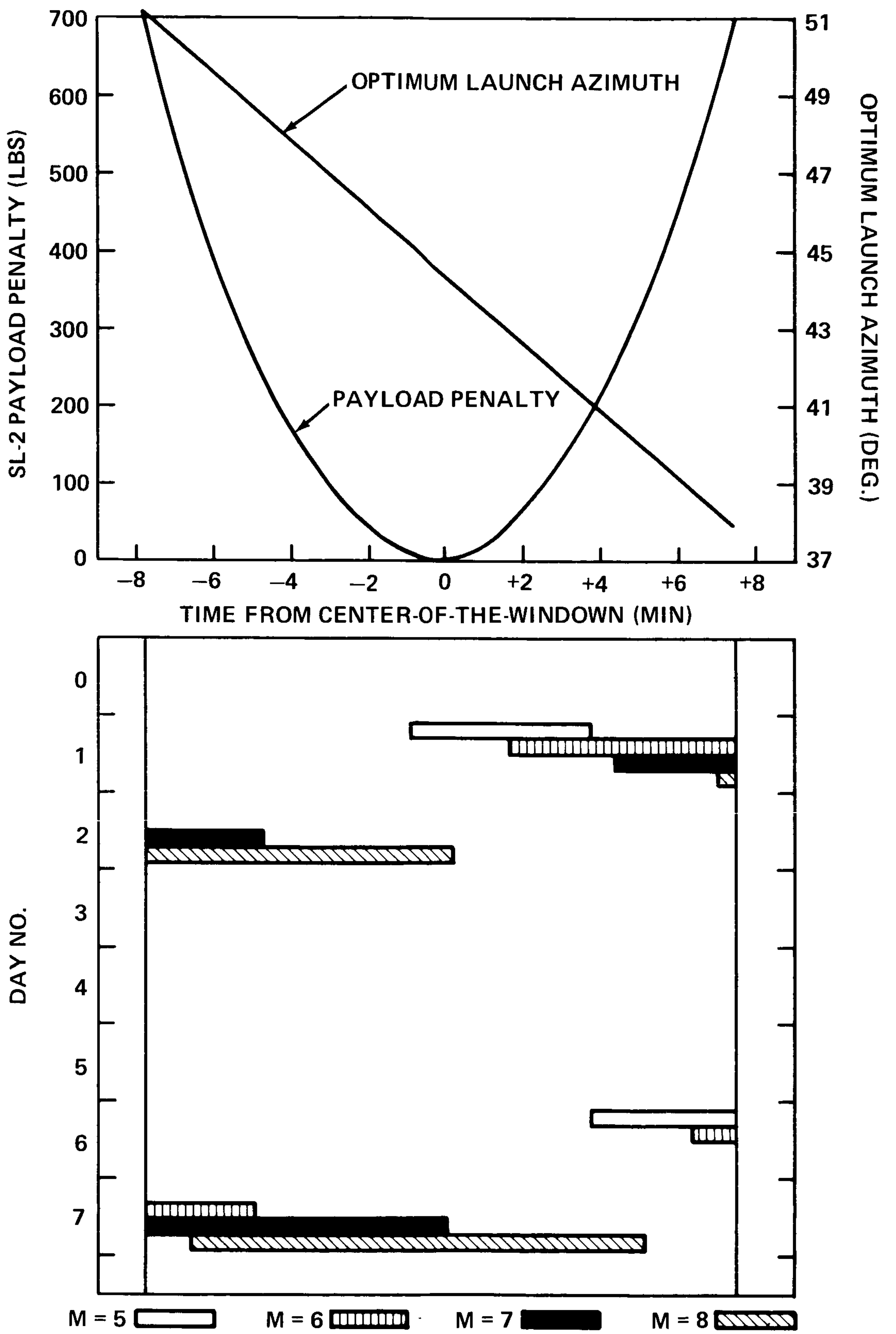

FIGURE 7 - SL-2 LAUNCH OPPORTUNITIES EXAMPLE 2 (PACIFIC OCEAN IMPACT)

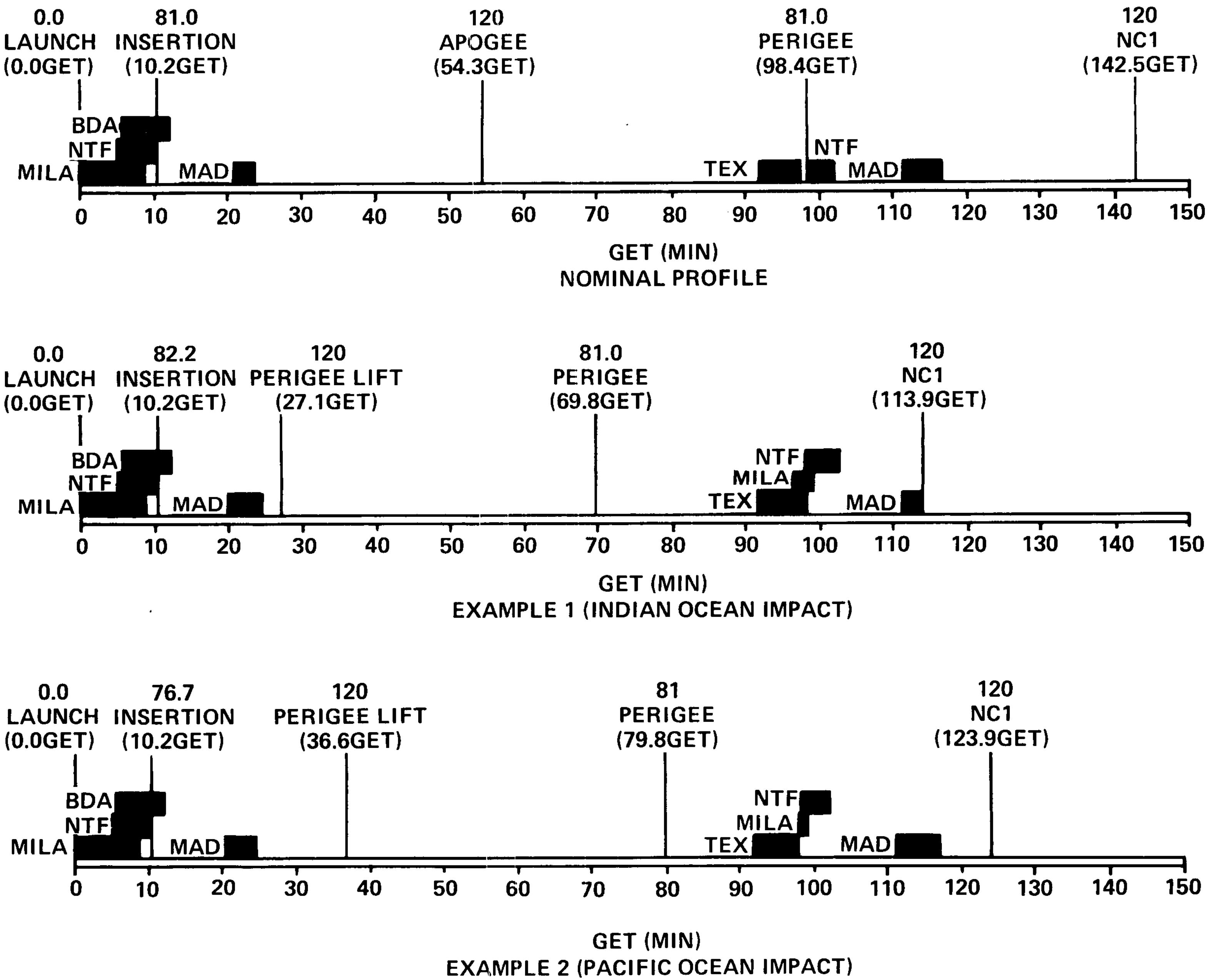

FIGURE 8 - SL-2 PRE-NC1 TRACKING, CENTER-OF-THE-WINDOW LAUNCH OPPORTUNITY

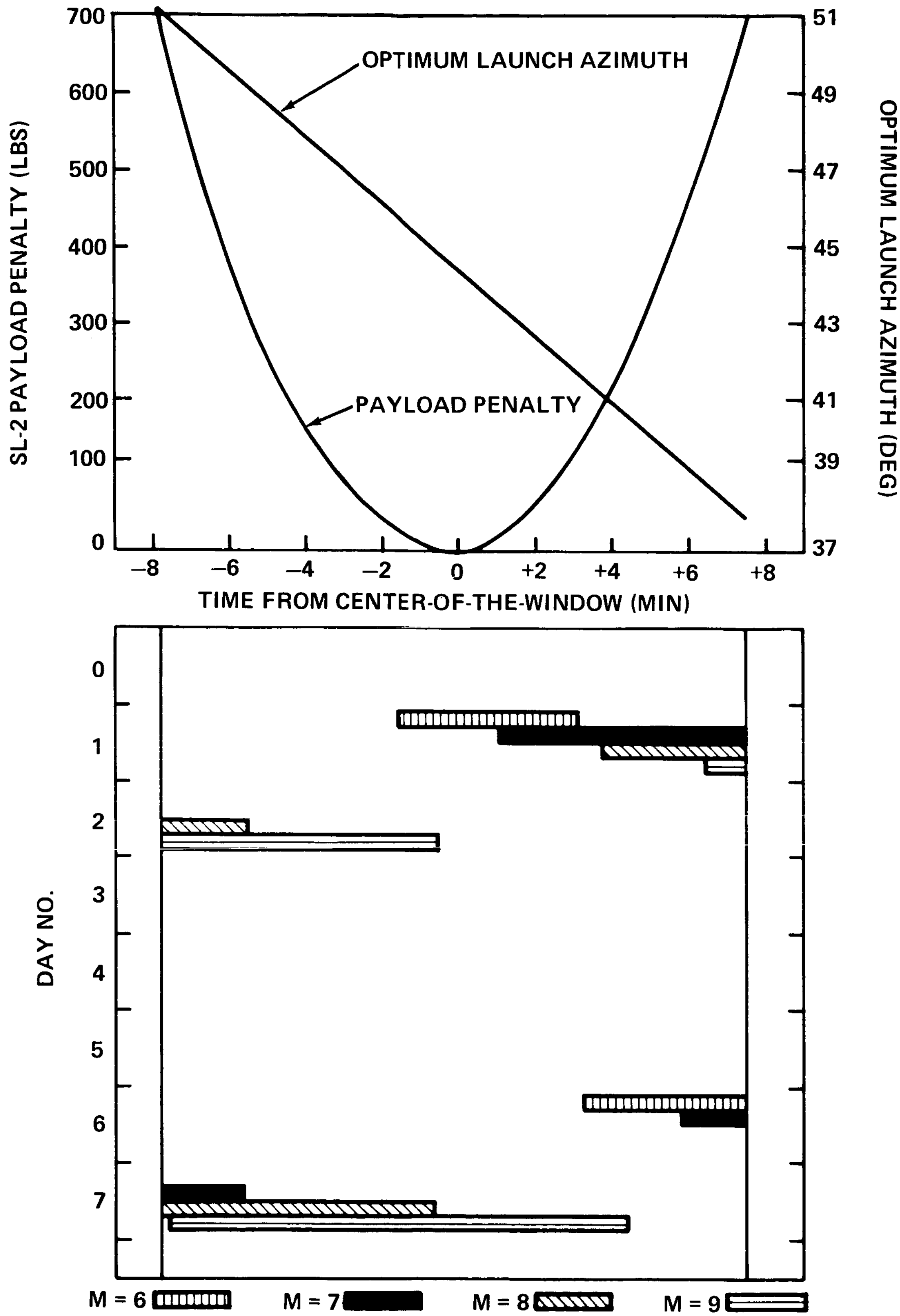

FIGURE 9 - SL-2 LAUNCH OPPORTUNITIES EXAMPLE 1 (INDIAN OCEAN IMPACT) 2 ORBITS FROM PERIGEE LIFT TO NC1, SL-1 INSERTION DESCENDING NODE IS 154.56 DEG

Subject: Controlled Oceanic Impact for Skylab S-IVB Stages - Case 610

From: W. L. Austin, P. H. Whipple

Distribution List

NASA Headquarters

H. Cohen/MLQ
J. H. Disher/MLD
C. R. Downs/MLO
W. B. Evans/MLO
J. P. Field, Jr./MLB
T. E. Hanes/MLA
E. L. Harkleroad/MLO
A. S. Lyman/MAP
M. Savage/MLE
W. C. Schneider/ML

MSC

A. A. Bishop/KM
R. E. Ernull/FA
E. M. Henderson/FM3
G. L. Hunt/FM13
K. S. Kleinknecht/KA
F. C. Littleton/KM
R. E. McAdams/FM3
P. C. Shaffer/FC5
S. A. Sjoberg/FA
H. W. Tindall/FA
K. A. Young/FM6

MSFC

L. F. Belew/PM-SL-MGR
R. H. Benson/S&E-AERO-MM
J. W. Cremin/S&E-AERO-MX
C. C. Hagood/S&E-CSE-A
O. M. Hardage/S&E-AERO-MF
B. S. Perrine/S&E-AERO-MMD
R. E. Tinius/S&E-CSE-AM

TRW - Houston

J. Lewis

Bellcomm

A. P. Boysen, Jr.
J. P. Downs
D. R. Hagner
W. G. Heffron
J. J. Hibbert
D. P. Ling
J. Z. Menard
J. M. Nervik
P. F. Sennewald
R. V. Sperry
J. W. Timko
R. L. Wagner
M. P. Wilson
Depts. 1011, 1013 Supervision
Departments 1022, 1024, 1025
Department 1024 Files
Central Files
Library